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Modern Trends in Service Test Equipment

PART I

By the Engineering Department, Aerovox Corporation

THE cavalcade of radio test equipment through the past decade has been punctuated here and there by the appearance of outstanding instruments of a highly specialized nature and wide utility. And the occurrence of these instruments has paved the way for the important transitions through which the business of trouble-shooting has passed.

From humble beginnings amongst the crudest electrical tools, the radio service art has advanced to require peculiar instrumentation which, when completely attended, is comparable in cost to the gear necessary to the practice of a profession such as dentistry, for instance. The growing complexity of receivers and electronic equipment has continually dictated new diagnostic methods, and each of these methods imposes new or improved instrument requirements. It will be the purpose of this article to review in brief some of the diagnostic methods lately adopted by leading experts in the field and to describe, as space permits, some of the equipment lately developed for the pursuit of those methods.

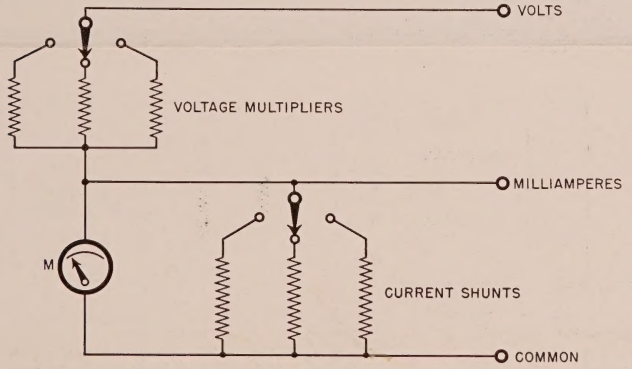

Figure 1A

THE COMBINATION METER

Perhaps the earliest piece of service test apparatus *per se* was the simple pocket volt-ammeter which was in wide use as late as 1925 for checking batteries and making random continuity tests in the receivers of that early day. Over a period of years, however, the simple meter took on additional useful features of particular radio value as new receiver complications demanded. Provision was made from time to time for the measurement of alternating as well as direct voltages, milliamperes, ohms, microfarads, decibels, and (in a very few cases) henries as well. The common volt-ohm-milliammeter and set analyzer emerged from this genesis.

The simple circuit employed in the volt-ohm-milliammeter is widely familiar. The volt-milliammeter d.c. section is reproduced in its essential elements in Figure 1A. Here it is seen that a series of voltage multiplier and current shunt resistors are used to convert the indicating meter (which may be any convenient milliammeter or microammeter) into a multi-range volt-milliammeter. The addition of a copper oxide bridge rectifier unit in

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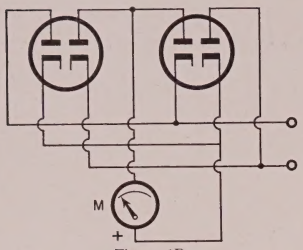


Figure 1B

the well-known manner renders the same instrument useful for alternating current measurements.

While any available milliammeter or microammeter may be used as the indicating instrument, it is highly desirable to keep the resistance of the circuit high for radio testing. Consequently, few if any V-O-M meters at present are rated lower than 1000 ohms per volt (a convenient value to obtain with a 0-1 d.c. milliammeter). Indeed, the anticipated demands of television testing and photocell checking in sound motion picture work have given rise to volt-milliammeters rated between 20,000 and 100,000 ohms per volt. Such high-resistance instruments employ low-range microammeters.

The multiplier resistors required for any chosen ranges may be calculated from Ohm's Law:

$$R = \frac{E}{I}$$

Where R is the required multiplier resistance,
E is the desired full-scale voltage reading
I is the present full-scale current reading of the instrument (in amperes)

The current shunts for any selected milliampere ranges may be determined from the formula:

$$R = \frac{R_m}{F-1}$$

Where R is the required shunt resistance,
R_m is the d.c. resistance of the meter,
F is the factor by which it is desired to alter the meter reading.

The accuracy of the d.c. portion of the combination meter is limited by the accuracy of the indicating meter and that of the multiplier and shunt resistors. Meters are commonly supplied with a guaranteed accuracy of 2% of full-scale deflection, and precision non-inductive resistors may be obtained at relatively low prices with an accuracy of 1/10 of one percent, so that the combination instrument can be held to an accuracy of 2.1 percent.

The a.c. accuracy of the unit is influenced, in addition to the above considerations, also by the inherent resistance of the copper oxide rectifier and notably by its frequency error. The latter is due to the capacitance between the rectifier discs which serve to bypass the higher frequencies, and the authors note widespread recent adoption of miniature tube rectifiers to obviate the shortcoming of the copper oxide device. The circuit of Figure 1B shows the manner in which two 6H6 diodes are connected in a bridge rectifier circuit to replace the copper oxide type. The heaters of these tubes, not shown, may be energized by a 6.3 volt filament transformer or they may be connected in series and operated from the a.c. line through a 322-ohm line cord resistor.

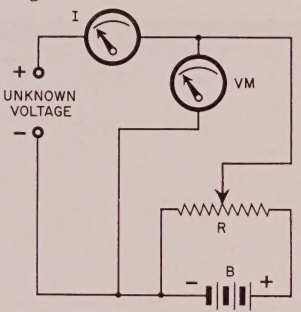


Fig. 2

The range of combination meters may be extended almost indefinitely simply by the proper choice of shunts or multipliers. This fact is borne out by the recent appearance of several moderately-priced d.c. kilovoltmeters recommended for checking high voltages in television systems.

INFINITE RESISTANCE METER

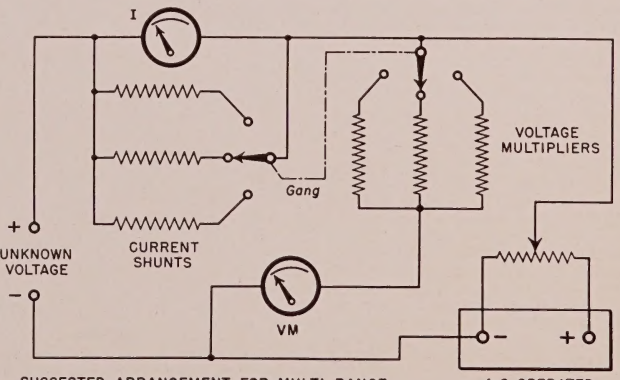
In a further attempt to meet the problem of measuring voltage accurately, but in a simple manner, in high-resistance circuits (such as a.v.c. networks) or at points where no power at all is to be drawn from the circuit under inspection, Browning, Gaffney, and Thompson* have suggested an interesting voltmeter with infinite input resistance.

The instrument, illustrated in Figure 2, is a direct current device and is manipulated somewhat in the manner of the familiar slide-back type of vacuum-tube voltmeter. Its zero-resistance characteristic is based upon the presence in the metering circuit of exactly equal and opposite voltages (the unknown and "balancing" voltages, respectively), a condition which prevents current flow.

I, is an ammeter, milliammeter, or microammeter; VM a d.c. voltmeter; B a battery or a.c.-operated power supply. The size of each of these components will be governed by the voltage range over which the instrument is to be operated. R is a suitable potentiometer for varying the bucking voltage delivered by B between zero and maximum.

The unknown voltage is applied to the terminals so marked and causes the current meter, I, to be deflected. The potentiometer, R, is then adjusted until meter, I, reads zero, whereupon the voltage delivered by the B-R combination is exactly equal to the unknown voltage and is indicated directly by the meter, VM.

A versatile measuring instrument of this type, as shown in Figure 3, might be constructed with the necessary switched shunts for meter, I, and multipliers for meter, VM, to provide an exceedingly wide range of operation. It is claimed for the device that its accuracy depends entirely upon the ability of the operator to balance the current meter, I, to zero. No definite percentage of accuracy has been stated for *all* voltage ranges in circuits of *any* resistance. The designers call attention, however, to their measurement of 5 volts in series with 10 megohms of resistance with less than 10 percent error.



SUGGESTED ARRANGEMENT FOR MULTI-RANGE INFINITE RESISTANCE VOLTMETER
A.C. OPERATED POWER SUPPLY
Fig. 3

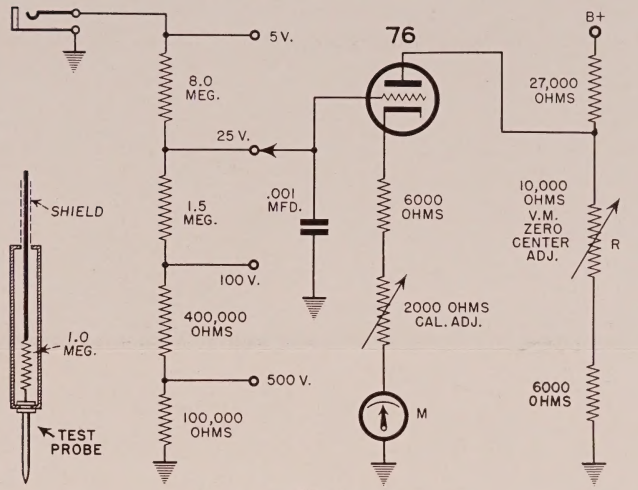


Fig. 4

ELECTRONIC D.C. VOLTMETERS AND OHMMETERS

To enable measurement of direct voltages at points such as the grid or plate terminal of a vacuum tube or in high-frequency oscillator, a.v.c., a.f.c., resistance-coupled, and high-fidelity audio circuits, without disturbing receiver or amplifier operation, the electronic d.c. voltmeter has recently been offered. By means of this instrument, operating and control voltages may be measured at points where a signal is present without upsetting the circuit, thereby permitting a test under dynamic operating conditions.

The circuit of the most popular electronic d.c. voltmeter, due to Rider (RCA-Rider Chanalyst), is shown in Figure 4. Here a triode is connected as a degenerative d.c. amplifier with a very high-resistance voltage divider in its input circuit. The input divider is so proportioned that a constant resistance of 10 megohms is offered to the external circuit, and the voltage actually applied to the grid of the triode never exceeds a maximum of 5. The meter, M, is generally a 0-1 m.a. instrument, and is so adjusted by varying the zero-adjuster resistor, R, that it reads zero at center scale. Thus either positive or negative polarity may be applied to the tube grid to obtain a reading. Each scale extends to the same maximum reading on each side of the middle zero.

Input to the voltmeter is generally through a conventional jack, as shown, which receives a plug at the end of a shielded cable. Inside one test probe is connected a 1-megohm resistor which serves to isolate the voltmeter and operator from the circuit under measurement.

From the combined resistance of the probe resistor and the voltage divider network, it is seen that the maximum current taken from an external circuit would be approximately 40 microamperes for 500 volts input and about 0.4 microampere for 5 volts input.

Another electronic d.c. voltmeter, also due to Rider (RCA-Rider Volt-Ohmyst), is shown in Figure 5. This is a balanced instrument possessing several obvious advantages: absence of circuit loading, since the input resistance of the instrument is 16 megohms up to 500 volts and 160 megohms between 500 and 5000 volts. Degeneration, obtained through the action of the two high-order cathode resistors, divorces instrument operation from tube characteristics. The high value of these cathode resistors acts at the same time, together with the low plate voltage used in this voltmeter, to reduce contact-potential error.

The indicating meter, M, receives a differential voltage developed across R and R_1 as a result of the simultaneous shift of plate currents in tube A and tube B in opposite directions when a voltage is applied to the grid of tube A. (A change of input voltage at the grid of tube A changes the cathode voltage of tube B through action of the coupling resistor, R_2 to accomplish this plate current shift).

A special probe, with a high-order resistor connected inside the sleeve, is used with the balanced voltmeter, as with the electronic meter described previously.

The instrument permits the measurement of resistance between 0.1 ohm and a million megohms, as shown in Figure 6. As commercially supplied, the device has all accessories self-contained to fit it for voltage and resistance measurements.

* Service, May 1938

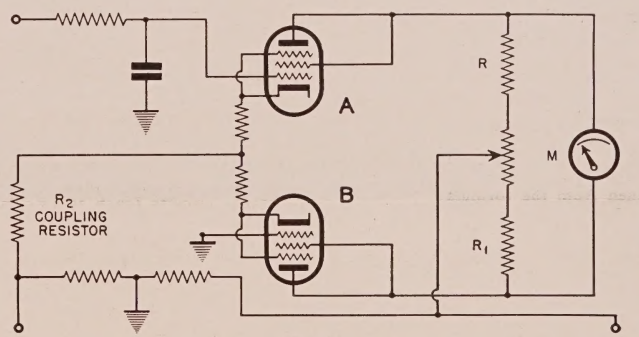


Fig. 5

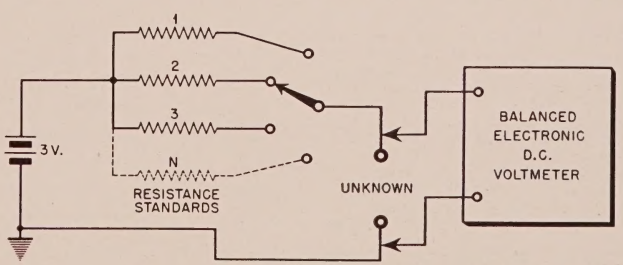


Fig. 6

Type PGM 8 mfd. 450-volt extra-compact wet electrolytic alongside a well-known packaged candy, for size comparison.

Wet ELECTROLYTIC CONDENSERS

● High capacity in minimum bulk; ability to take severe punishment and come back for more; low-cost capacity and working voltage; long life—those are the outstanding attractions of the Aerovox wet electrolytics.

The use of liquid electrolyte permits the reforming of the dielectric film following voltage breakdown. However, the liquid electrolyte imposes certain problems for the manufacturer of such condensers. There must be perfect sealing to avoid the leakage of electrolyte and consequent corrosion of the chassis and components. Also, there must be adequate venting whereby to relieve excessive gas pressures.

In Aerovox "wets", these and other critical requirements have been met. The unique Aerovox vent provides instant escape of any gas pressure, yet effectively double-seals the metal container against leakage of liquid electrolyte.

Available in the 1" diameter Type PGM (extra-compact) and the larger diameters Type PG types, as listed.

600 Volts Peak—Type PG600

Cap. Mfds.	Can Size-Ins. Dia.-High	List Price	Net Price
4	1⅜ x 3-7/16	$1.35	$0.81
8	1⅜ x 4-7/16	1.50	.90
16	1½ x 4-15/16	2.00	1.20

500 Volts Peak—Type PG500

4	1⅜ x 3-1/2	$0.80	$0.48
6	1⅜ x 3-1/2	.85	.51
8	1⅜ x 3-1/2	.95	.57
10	1⅜ x 3-1/2	1.05	.63
12	1⅜ x 3-1/2	1.15	.69
16	1⅜ x 4	1.35	.81
18	1⅜ x 4	1.50	.90
20	1⅜ x 4-1/2	1.50	.90
25	1½ x 4	1.65	.99
30	1½ x 4-1/2	1.70	1.02
35	1½ x 4-1/2	1.75	1.05
40	1½ x 4-1/2	1.90	1.14

350 Volts Peak—Type PG350

8	1⅜ x 3-1/2	$0.90	$0.54
16	1⅜ x 3-1/2	1.10	.66
20	1⅜ x 3-1/2	1.40	.84
40	1½ x 4	1.80	1.08

500 Volts Peak—Type PGM500

Cap. Mfds.	Can Size-Ins. Dia.-High	List Price	Net Price
4	1 x 3-1/2	$0.80	$0.48
6	1 x 3-1/2	.85	.51
8	1 x 3-1/2	.95	.57
10	1 x 4	1.05	.63
12	1 x 4-1/2	1.15	.69
16	1 x 4-1/2	1.35	.81

350 Volts Peak—Type PGM350

8	1 x 3-1/2	$0.90	$0.54
16	1 x 4-1/2	1.10	.66
20	1 x 4-1/2	1.40	.84

250 Volts Peak—Type PGM250

8	1 x 3-1/2	$0.80	$0.48
16	1 x 4-1/2	.90	.54
24	1 x 4-1/2	1.00	.60
35	1 x 4-1/2	1.15	.69
40	1 x 4-1/2	1.20	.72

150 Volts Peak—Type PGM150

8	1 x 3-1/2	$0.70	$0.42
16	1 x 3-1/2	.80	.48
24	1 x 3-1/2	.90	.54
35	1 x 4-1/2	1.05	.63
40	1 x 4-1/2	1.15	.69

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● He'll gladly show you these Aerovox "wets". Use them in that assembly subject to surge or peak voltages. Ask your jobber for the latest Aerovox catalog—or write us direct.

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